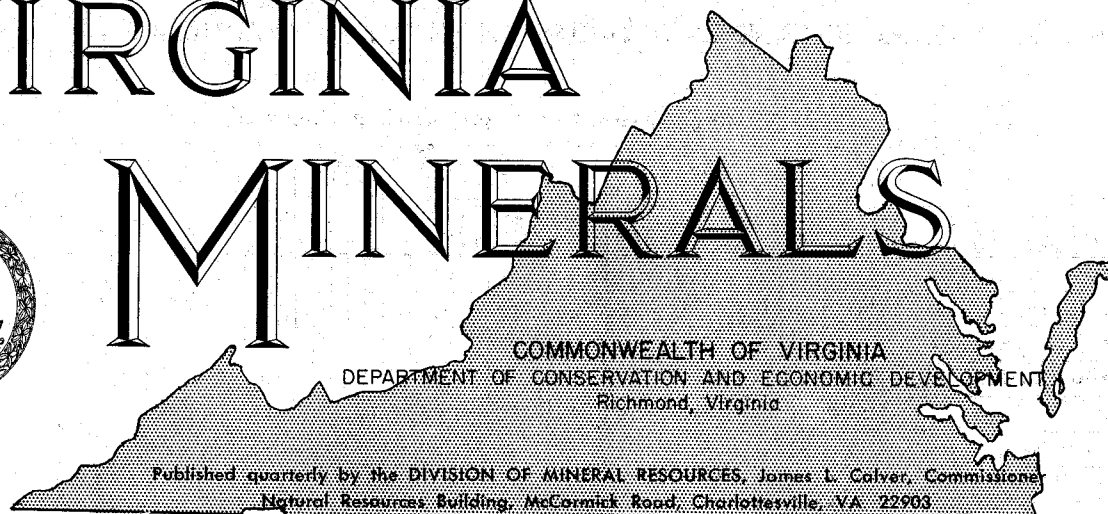


VIRGINIA



MINERALS



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GEM STONES¹

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INTRODUCTION

The centennial of the Great Diamond Hoax (1) has passed virtually unnoticed. In 1870, gold miner Philip Arnold quietly purchased several large parcels of gem rough from European diamond merchants. The following year he and his partner salted diamonds, rubies, and emeralds on a mesa near Rawlings Springs, there to be "discovered" by potential investors. Unfortunately, one of the gems was already faceted and so the hoax came to a sudden conclusion.

Gem collecting has come a long way since then. The trade magazine *Lapidary Journal* (6) lists more than 1500 dealers and 1000 clubs in this country, from Altoona, Pa. to Nome, Al. As a hobby it has a lot to offer: rockhounding, trading, tumbling, faceting, and jewelry design.

Although in twentieth century America diamonds are a girl's best friend, it wasn't always so. Several notable changes regarding the principal gems and their sources have occurred through the ages. Prior to 3000 B.C., Phoenician traders popularized amber, a fossilized pine resin of succinite found in Baltic Sea deposits. Then for the next 2000 years the turquoise and emerald mines

near the Red Sea supplied gems for the Egyptian pharaohs, while, coincidentally, the same two minerals were mined in Mexico and Colombia by the Aztecs and Incas. Apache Indians, believing turquoise assured accuracy in aim, used to fix it to their bows and rifles.

In China, jade reigned supreme, for, according to Confucius, "In ancient times men found the likeness of all excellent qualities in jade." Legend has it that only the first wife could wear jade, the second having had to content herself with diamonds and rubies. Jade carving began in the neolithic era with the use of nephrite, an amphibole mineral from Sinkiang province. Jadeite, a precious green pyroxene from Burma, was not used until the eighteenth century.

From 800 B.C. to 1700 A.D., India and Ceylon were the chief sources of diamonds, rubies, and sapphires. However, following the diamond discoveries of 1727, Brazil became the leading producer only to be supplanted by South Africa in 1870. Spurred on by a strategic materials embargo, the Russians discovered vast diamond deposits in Siberia in 1955 and today these rival the African fields.

About sixty varieties of precious stones are found here in the United States, but only the once-active sapphire deposits of Montana and turquoise mines in the southwest were million dollar commercial ventures. Annual domestic pro-

¹ Reprinted in part from *Earth and Mineral Sciences*, October 1970.

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Single-Crystal Gemstones and their Properties

Gemstone	Chemical Formula	ρ	H	\bar{n}	Δ	Crystal Class	Crystal Size	Max. Optics	Max. Price Range \$/ct.	Rough Price Range \$/ct.	Colors							Chief Source	Remarks for Faceting (2)
											Red (Pink)	Orange	Yellow	Green	Blue	Violet	Colorless		
ANDALUSITE	Al_2SiO_5	3.15	7 $\frac{1}{2}$	1.64	.016	mmm	B-	10	.5- 1.5					x				Brazil	Orient to show pleochroism. Tough and strong.
APATITE	$\text{Ca}_5\text{P}_3\text{O}_{12}\text{F}$	3.20	5	1.64	.013	6/m	U-	30	.2- 2.5				x	x	x	x		Mexico	Lovely pale colors, but brittle and heat sensitive.
AXINITE	$\text{Ca}_2\text{MnAl}_2\text{BSi}_4\text{O}_{16}\text{H}$	3.28	7	1.68	.01	$\bar{1}$	B-	50	.1- .5								x	Mexico	Color and hardness vary with direction. Brittle.
BENITOITE	$\text{BaTiSi}_3\text{O}_9$	3.67	6 $\frac{1}{2}$	1.78	.046	6m2'	U+	2	2.0- 5.0						x			Calif.	Beautiful blue crystals but usually too small.
BERYL	$\text{Al}_2\text{Be}_3\text{Si}_6\text{O}_{18}$	2.70	7 $\frac{1}{2}$	1.58	.014	6/mmm	U-	50	.1-100.	x	x	x	x				x	Brazil	Emerald expensive. Other hues pale, but cut and polish well.
BRAZILIANITE	$\text{NaAl}_3\text{P}_2\text{O}_{12}\text{H}_4$	2.94	5 $\frac{1}{2}$	1.60	.014	2/m	B+	30	.5- 2.0			x						Brazil	Attractive yellow, similar to apatite. Avoid cleavage.
CHRYSOBERYL	Al_2BeO_4	3.71	8 $\frac{1}{2}$	1.75	.015	mmm	B+	10	.3- 10.0	x	x	x					x	Brazil	Yellow stones small but durable. Alexandrite expensive.
CORDIERITE	$\text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18}$	2.59	7	1.54	.017	mmm	B-	10	.1- 1.0					x	x			India	Very pleochroic; orient to show blue. Usually flawed.
CORUNDUM	Al_2O_3	4.00	9	1.76	.018	3m	U-	100	.1-100.	x	x	x	x	x	x	x	x	Synthetic	Begin with colorful, inexpensive synthetics. Hard and tough.
DANBURITE	$\text{CaB}_2\text{Si}_2\text{O}_8$	3.00	7	1.63	.016	mmm	B-	10	.1- .5								x	Mexico	Water clear crystals which take an excellent polish.
DIAMOND	C	3.52	10	2.42	.044	m3m	I	5	50. -500.			x					x	Africa	Difficult to obtain. Special lapidary equipment required.
DIOPSIDE	$\text{CaMgSi}_2\text{O}_6$	3.29	5 $\frac{1}{2}$	1.70	.01	2/m	B+	10	.3- 1.0			x						Malagasy	Dark color. Splits easily parallel to cleavage planes.
ENSTATITE	MgSiO_3	3.27	6	1.67	.01	mmm	B+	10	.1- .3								x	India	Dark and difficult to facet, like diopside.
GARNET	$\text{Mg}_3\text{Al}_2\text{Si}_3\text{O}_{12}$	3.9	7 $\frac{1}{2}$	1.80	.026	m3m	I	50	.1- 5.0	x	x	x	x					Tanzania	Most large stones too dark. Somewhat heat sensitive.
KYANITE	Al_2SiO_5	3.67	6	1.72	.020	$\bar{1}$	B-	10	.2- .5					x	x			Brazil	Recommended for experts. Very troublesome cleavage.
OLIVINE	Mg_2SiO_4	3.34	6 $\frac{1}{2}$	1.68	.020	mmm	B+	10	.2- 2.0				x					Arizona	Small coke-bottle green crystals. Fairly tough.
ORTHOCLASE	KAlSi_3O_8	2.56	6	1.53	.012	2/m	B-	30	.1- .3			x					x	Malagasy	Madagascar stones clear and brilliant. Avoid cleavage.
QUARTZ	SiO_2	2.65	7	1.55	.013	32	U+	100	.1- 2.0	x	x	x	x	x	x	x	x	Brazil	Splendid material for practice: inexpensive and tough.
RUTILE	TiO_2	4.25	6	2.75	.28	4/mmm	U+	100	.3- .5			x					x	Synthetic	Synthetic titania, very brilliant. Mineral specimens dark.
SCAPOLITE	$\text{Na}_4\text{Al}_3\text{Si}_9\text{O}_{24}\text{Cl}$	2.67	6	1.56	.017	4/m	U-	10	.2- .5			x					x	Brazil	Pale, glassy appearance. Brittle. Collector's item.
SPHALERITE	ZnS	4.09	3 $\frac{1}{2}$	2.37	.156	43m	I	30'	.1- .3	x	x							Spain	Brilliant when free of inclusions, but too soft.
SPHENE	CaTiSiO_5	3.53	5	1.96	.051	2/m	B+	5	.2- 2.5			x	x				x	Mexico	Very fiery when not too dark, fairly brittle.
SPINEL	MgAl_2O_4	3.60	8	1.72	.020	m3m	I	100	.1- 2.5	x	x	x	x	x	x		x	Synthetic	Natural stones small and dark. Synthetics bright and cheap.
SPODUMENE	$\text{LiAlSi}_2\text{O}_6$	3.18	7	1.67	.017	2/m	B+	50	.1- 1.0	x		x	x				x	Brazil	Large clear crystals in pale shades. Tricky cleavage.
STRONTIUM TITANATE	SrTiO_3	5.13	6	2.41	.19	m3m	I	50	1.0- 3.0								x	Synthetic	Except for hardness, an excellent substitute for diamond.
TOPAZ	$\text{Al}_2\text{SiO}_4\text{F}_2$	3.54	8	1.63	.014	mmm	B+	100	.1- 4.0	x	x	x	x	x	x	x	x	Brazil	Practice on inexpensive colorless crystals. Avoid basal cleavage.
TOURMALINE	$\text{CaMg}_3\text{Al}_6\text{B}_3\text{Si}_6\text{O}_{31}\text{H}_3$	3.06	7	1.63	.017	3m	U-	20	.2- 3.0	x	x	x	x	x	x	x	x	Brazil	Orient carefully for best color. Unusual color banding.
ZIRCON	ZrSiO_4	4.6	7	1.96	.039	4/mmm	U+	10	.5- 1.0	x	x		x	x	x	x	x	Ceylon	Most bright-colored stones heat treated. Brittle but tough.
ZOISITE	$\text{Ca}_2\text{Al}_3\text{Si}_3\text{O}_{13}\text{H}$	3.36	6 $\frac{1}{2}$	1.70	.01	mmm	B+	20	3.0- 10.0							x	x	Tanzania	Excellent blue color, but some are heat-treated and sensitive.

Key: ρ - specific gravity \bar{n} - average refractive index U - uniaxial I - isotropic
H - Mohs hardness Δ - chromatic dispersion B - biaxial * - optic sign

duction for all gems is currently estimated (10) at \$2,500,000, and is almost entirely a recreational activity.

COMPOSITION

The principal gems and their sources, properties, and cutting characteristics are summarized in the table. More detailed information may be found in the gemology books by Webster(4), Smith(5), and Sinkankas(2,3). Since only transparent single-crystal gems are included in the table, jade, turquoise, and other polycrystalline ornamental stones have been omitted. Most of the minerals and synthetics listed are currently avail-

able from American dealers(6). The prices given refer to uncut gem rough in the two carat size range and are necessarily *very* approximate as, for instance, depending on origin and quality, ruby prices vary over five orders of magnitude!

Like a good wife, a gem is something unusual, a beautiful thing with plenty of sparkle, and strong enough to withstand normal wear and tear. Its physical properties are determined by its chemical composition and crystal structure, and the hardest minerals are those with strong covalent bonding or dense-packed ionic lattices. The bonding must be strong in all directions, otherwise cleavage occurs, thereby making faceting difficult, as with spodumene and topaz. The

sparkle and "fire" of a gemstone are also determined by the electronic structure. Diamond, rutile, and other brilliant gems have intense absorption bands in the near ultraviolet, giving rise to strong dispersion and high refractive indices for visible radiation.

COLOR

Some colors are more popular than others, with most people preferring rich-hued blues, reds, and greens, so accounting in large measure for the popularity of the sapphire, ruby, and emerald. Purple and orange stones are considered to be of somewhat less value, while yellow and brown lag far behind.

The color of most gems is caused by atoms with incomplete electron shells, usually a transition-metal element, although zircon and apatite are colored by transuranic and rare-earth ions. Only small concentrations of these ions are needed to produce crystal-field absorption spectra. Thus, ruby and sapphire, the corundum gems, differ by about 1% in chemical composition: in ruby a few aluminum ions are replaced by chromium, whereas traces of iron and titanium are found in blue sapphire. Sapphire is an excellent example of charge compensation (8). The presence of tetravalent titanium keeps iron in the divalent state, producing the blue color.

Light absorption is caused by electronic transitions, usually $d \rightarrow d$ transitions, which are weakly allowed in crystals. In viewing a gem, the eye sees the complementary color to the wavelength absorbed by the transition-metal ion. In chrysoberyl, for example, traces of Fe^{3+} absorb violet and indigo to give the stone the complementary color, yellow.

Chromium-bearing chrysoberyl, alexandrite, named for Czar Alexander II of Imperial Russia, whose official colors were red and green, exhibits an unusual color-change phenomenon. In daylight it is green, while in the evening, under incandescent illumination, it is red. A delicately balanced absorption spectrum and the temperature difference of the light sources are responsible for this color change. In fact, alexandrite absorbs all colors except red and green; the latter dominates in daylight because the sun radiates light at $6000^{\circ}C$, giving off a blackbody spectrum which peaks in the green. A higher proportion of longer wavelengths are emitted by the cooler (2000°) tungsten-filament light bulbs making alexandrite appear red at night.

Pleochroism refers to the variation of color with direction, an effect which yields some pleasing color combinations in faceted stones. When properly oriented, step-cut andalusite shows reddish-brown crown facets and a contrasting green table facet. The metamorphic gem mineral, cordierite, exhibits even more remarkable pleochroism. Its colors are violet, blue, and yellow along the three principal axes. As a gem, it is usually oriented to give a sapphire blue color, but the Vikings had a much more important use for the stone. Those sturdy sailors employed cordierite as a sunstone, a navigational aid used near the north pole where compasses are unreliable and a mistake meant freezing to death. In far northern waters, the sun is often below the horizon or obscured by clouds. At grazing incidence, the sunlight scattered by clouds directly overhead is strongly polarized, and the sunstone allows one to determine the direction of polarization and, hence, the position of the sun. Indeed, Danish archeologist Thorkild Ramskou has demonstrated 2° accuracy for the Viking sunstone.

Star sapphire, chrysoberyl cats eye, moonstone, and a few other translucent gems show curious light-scattering effects caused by oriented inclusions. The rainbow colors of opal are also a light-scattering phenomenon. Its microstructure consists of tiny silica spheres arranged in close-packed arrays resulting in beautiful diffraction effects when the sphere diameters are comparable to the wavelength of light. Bragg's law can be used to relate the colors to the sphere size and directions of illumination and observation (7).

When purchasing a colored gem, the buyer should examine it under several different lighting conditions, for stones showing a bright color under the intense illumination of a jeweler's counter may be too dark for evening wear. Coloring is seldom uniform because of compositional gradients, and except for watermelon tourmalines, patchiness is undesirable. A clever lapidary can flood an amethyst with purple by correctly positioning its color patches.

CLARITY

It was Pascal who said, "Nature has perfections, in order to show that she is the image of God; and defects, to show that she is only his image." To some, a gem crystal is the epitome of perfection, yet it has defects.

Fracture lines, incipient cleavage planes, bubbles, feathers, inclusions and other imperfections

generally detract from the transparency of a gem, and from its value as well. In transparent faceted gems, flaws directly beneath the table facet are especially visible and undesirable. Expert lapidaries usually position the imperfections beneath the crown facets, where they are obscured from view. Some minerals contain far more inclusions than others; perfect emeralds, for example, are very rare and very expensive.

Microscopic examination is useful in identifying the country of origin of a gem and in distinguishing natural and synthetic stones. Flame fusion grown synthetic ruby contains gas-filled bubbles and curved growth lines, whereas the more expensive mineral specimens often show two-phase inclusions (liquid plus gas) and hexagonal color banding.

Certain "fancy" diamonds, smoky quartz, and dark zircons, owe their color to radiation damage. Annealing the crystals at certain oven temperatures often removes the damaged regions, thereby producing dramatic color changes. "Cooking recipes" for dark brown low-zircon abound; to produce heavenly "starlite" zircon, one expert recommends heating for six hours in ferrocyanide fumes. After such an exposure, zircon reportedly turns blue and stays that way. Incidentally, this method of testing has been used in the California gas chamber.

COMMONNESS

Included in the table are a number of uncommon gems, that are of interest as collectors' items and conversation pieces. Whether it be a scarce mineral like the all-American benitoite found only in California, or one with an unusual color, such as the bright orange sapphire padparadschah, an uncommon stone adds interest to jewelry. Unfortunately, some rare minerals, such as the glassy-looking beryllonite, have little to recommend them *except* their rarity. About a hundred different crystals are faceted as gemstones, and assembling a complete collection is a challenge comparable to philately.

Synthetics are another consideration. Gem quality sapphires, spinels, and emeralds have already been grown, and the list will increase in the years ahead. For economic reasons, rare gems of complex chemistry are less likely to be synthesized, so that the rare become rarer, and the rich become richer.

About every ten years or so an entirely new gem is discovered, creating a stir amongst gemol-

ogists: Brazilianite in the forties, sinhalite in the fifties, and, most recently tanzanite in the sixties. There are few true-blue gemstones and when tanzanite came along it was big news (9). In 1967, pockets of sapphire-colored zoisite crystals were discovered by Manuel de Souza, a Goanese prospector, who stood guard over the site with a shotgun. The precise locality is still in question, but it is thought to be somewhere in the foothills of Mt. Kilimanjaro in Tanzania, the African state previously known as Kenya. Named Tanzanite, blue zoisite owes its pleochroic colors to the rare element vanadium. Many of the gems have been heat-treated to intensify the color, possibly by altering the valence state of vanadium from +3 to +4. Manhattan's Tiffany & Co. popularized the stone, which today sells at prices from \$20/carat and up.

CUTTING

Although expensive stones are occasionally shaped unsymmetrically to preserve weight, most jewels are faceted in one of the basic styles illustrated in Figure 1. The brilliant, or one of its modifications, is preferred for colorless gems because it emphasizes brightness and dispersion. For colored stones, the rectangular cushion or emerald styles with fewer facets give a clearer view of the body color. Intensely colored stones, such as almandine garnet, are cut in small sizes, with the lapidary sometimes deliberately departing from ideal proportions. To reduce the path length for absorption within the crystal, intensely colored gems are "shallowed-up," thus yielding a lighter color.

Top and cross-section views of the brilliant cut used for diamond engagement rings are shown in Figures 1 and 2, respectively. Neglecting the forty-one smaller facets, the brilliant consists of a large table facet surrounded by eight crown faces on top and eight pavilion facets forming a pyramid in back. The shape is specified by the crown and pavilion angles, Φ and Ψ , and the table to girdle ratio, T/G (Figure 2). Ideal proportions (2) vary slightly with refractive index, but approximate 40° for Ψ and Φ and 0.55 for T/G. The reasoning behind this choice is as follows. In rings and pendants, faceted stones are illuminated and observed in nearly parallel directions, as indicated by the dashed light path in Figure 2. Therefore, to maximize brightness, the incident light is collected and returned to the observer by total reflection from the rear pavilion facets.

If brightness were the only criterion, a simple 45° prism would suffice, but dispersion is important as well. The beauty of a diamond is enhanced by the rainbow hues of refracted and dispersed light; this is the principal role of the crown facets. The ideal proportions of a brilliant can be chosen to meet the following conditions: (1) All light rays entering and leaving the crystal are vertical, normal to the table facet. (2) Light rays entering near the *center* of the table facet exit near the *inside* of a crown facet, after total reflection from two pavilion faces. (3) Rays entering the *outside* of the table facet are again totally reflected from the rear facets and exit near the *outside* of a crown facet, close to the girdle. Conditions (2) and (3) ensure that all vertically incident light is dispersed since it either enters or exits through crown facets.

Applying the laws of refraction and reflection to a brilliant of refractive index n , the three conditions can be written as equations:

- (1) $\sin \Phi = -n \sin (\Phi + 4 \Psi)$
- (2) $(T/G) (\tan \Phi - \cot 4 \Psi) = \tan \Psi + \tan \Phi$
- (3) $(3 - (T/G)) \tan^2 \Psi = 1 + (T/G)$

Solving the equations numerically gives the ideal proportions in Figure 2, where Φ , Ψ , and T/G are

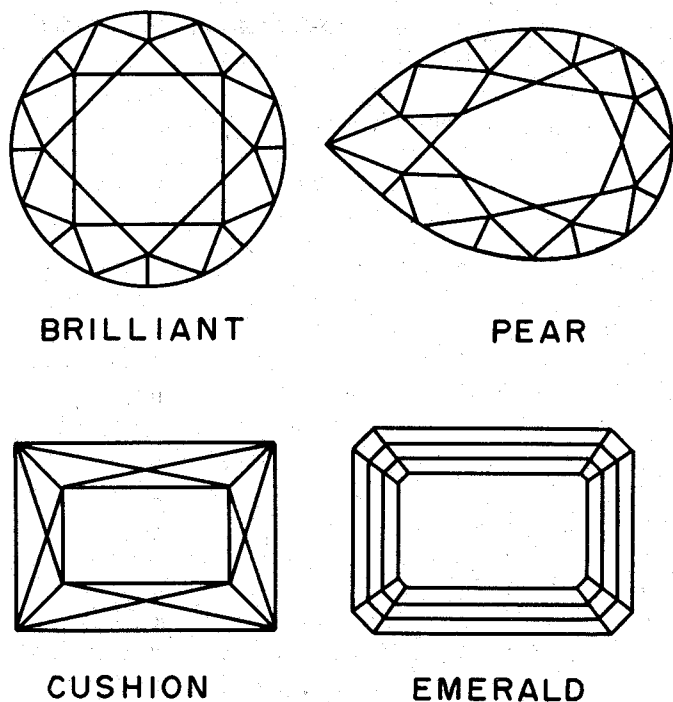


Figure 1. Top views of four common faceting styles. Most engagement rings are cut as brilliants or modified brilliants, the pear, marquise, pendolque and heart styles. Crown facets of the cushion style are cut in both the scissors (as shown) and step styles, as illustrated for the emerald (or octagon) cut.

plotted as a function of refractive index n . Thus, the proportions for diamond, for example, with $n=2.41$, are crown angle $\Phi = 41.0^\circ$, pavilion angle $\Psi = 38.7^\circ$, and table-to-girdle ratio $T/G = 0.56$. Neither Ψ nor T/G are sensitive to n , but Φ varies inversely with refractive index, as recommended by Sinkankas (2).

Gems are more brilliant when kept clean. It is particularly important to keep the pavilion facets grease-free, otherwise the conditions for total reflection are not satisfied and light is consequently lost by refraction. Mathematically, total reflection for a brilliant of refractive index n requires an outside refractive index $n_o < n \sin \Psi$, a condition easily satisfied for air ($n_o \sim 1$), but not for grease ($n_o \sim 1.5$). The resulting loss of brilliance is very obvious in gems of low refractive index, but even diamond brightens considerably when scrubbed with a toothbrush and ammonia.

When purchasing a gem, the faceting should be examined carefully for signs of over-polishing; four or more facets should meet at a point and symmetrically positioned facets should be equal. Chipping often occurs around the girdle, and the polish should be inspected for signs of "paper wear," scratches caused by mutual rubbing within the same paper packet.

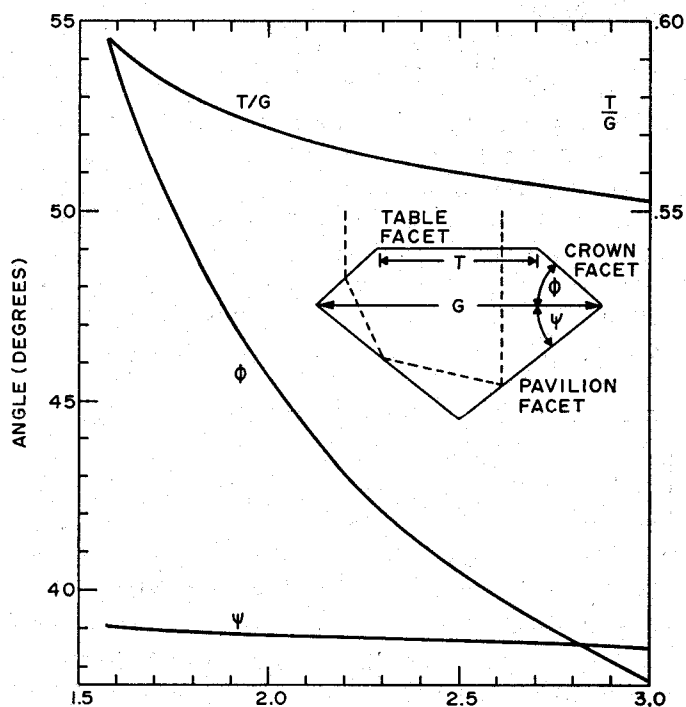


Figure 2. Ideal crown (Φ) and pavilion (Ψ) angles, and table-to-girdle ratio (T/G) plotted as a function of refractive index. Cross section shown in insert shows typical light path (dashed line).

CARATS

The weight of a gemstone is measured in carats (1 ct. = 0.2 grams), with larger stones commanding a higher price per carat than smaller ones. For example, a flawless five carat pigeon-blood ruby is worth about \$20,000, whereas one carat stones of the same quality retail for less than \$1000. The same is true for diamonds. Gem-quality diamonds larger than two carats are currently in short supply and the prices have risen faster than average, a result of American affluence. In fact, during the past few years the average engagement ring has doubled in size to 0.7 carats.

The buyer of inexpensive jewelry should remember that with items containing quartz or spinel, the intended use is more important than the cost. Very large pieces of this type of jewelry appear ostentatious and a good yardstick to keep in mind is that one to five carats is a reasonable size for rings, five to ten for pendants, and earrings over ten carats are definitely hard on the lobes.

COST

In the old days man captured his mate, tied her hands, and carried her off to his cave. Soon the hand-tying became symbolic with a ring of woven grass and then, much later with the advent of diamond engagement rings, it became expensive. This country now imports half-a-billion dollars in diamonds annually, about equally divided between cut and uncut stones (10). Sixty percent of the diamond rough is sold through the London offices of the Diamond Trading Corporation, while most of the faceting is done by Belgian and Israeli diamond cutters.

Since World War II diamond prices have been fairly stable, which hardly recommends them as a hedge on inflation, as is popularly supposed. In 1949 the U.S. imported 335 thousand carats in faceted diamonds valued at 41 million dollars, an average of \$122 per carat. Nearly twenty years later in 1968, tariff commissioners reported imports of 1,834,000 carats valued at \$222 million, or \$121 per carat (10)! Insurance costs (about 3% annually) are other factors to be considered by gem investors.

In spite of the fact that diamonds continue to dominate the trade with 90% of the business, colored stone imports have shown a rapid increase during the past few years (Figure 3). Pearl imports, however, are down about 50% since 1966.

Some collectors consider lesser known gems a better investment than diamonds, although the evidence is scanty. Around the turn of the century, faceted aquamarine and tourmaline were selling at ten dollars a carat, comparable to today. Except for diamonds, gem marketing is not controlled and it therefore depends markedly on supply. When a strike is made of an unusual stone, such as axinite or sphene, prices undergo rapid variations until the new supply is absorbed. Gem dealers naturally attempt to buy low and sell high, emulating their cousins on the stock market.

As in other fields of endeavor, gem buying requires experience. When examining stones at

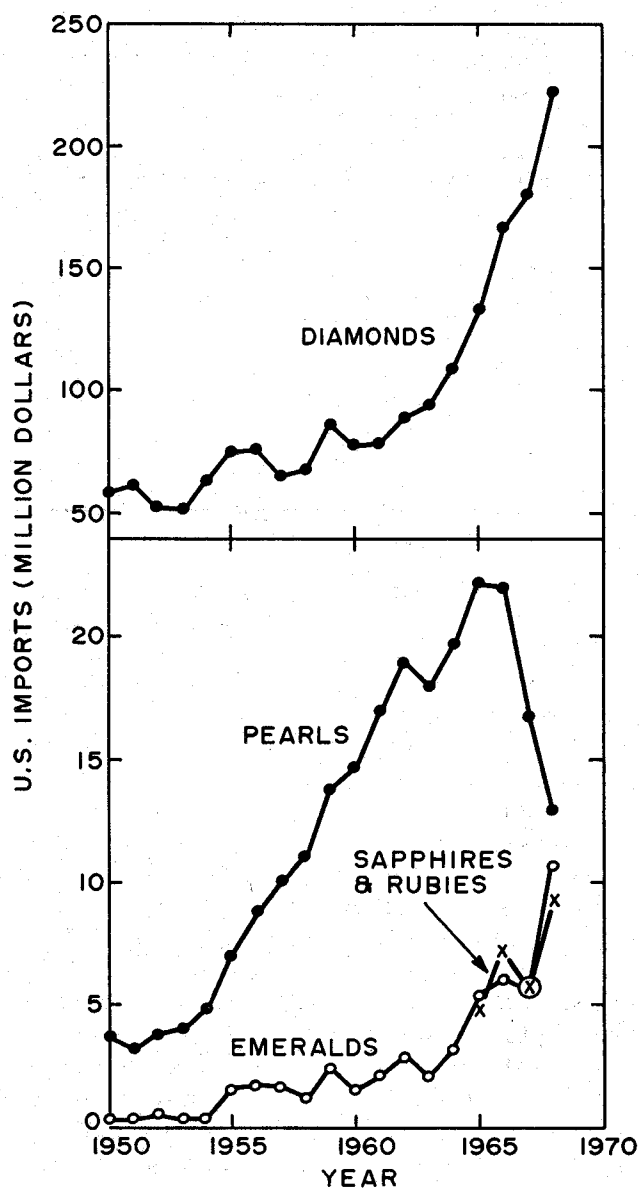


Figure 3. Annual U. S. imports for consumption of precious and semiprecious gem stones, cut but unset. Pearl imports are 90% cultured.

the local rock shop or jewelry store, remember the Seven C's are a useful guide: Composition, Color, Clarity, Commonness, Cutting, Carats, Cost—and *Compare*.

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PRESIDENT SIGNS NATIONAL MINERALS POLICY BILL¹

President Nixon on Dec. 31, 1970 signed S. 719, a bill to establish a national mining and minerals policy; it is now PL 91-631. The new law establishes, as a continuing national policy, the need to foster and encourage private enterprise in (1) the development of economically sound and stable domestic mining, minerals, metals and mineral reclamation industries; (2) the orderly and economic development of domestic mineral resources, reserves, and reclamation of metals and minerals to help assure satisfaction of industrial and security needs; (3) mining, mineral, and metallurgical research, including the use and recycling of scrap; and (4) the study and development of methods for the disposal, control, and reclamation of mineral waste products, and the reclamation of mined land, so as to lessen any adverse impact of mineral extraction and processing upon the physical environment that may result from mining or mineral activities.

¹ Excerpts from news bulletin of American Mining Congress, January 8, 1971.

NEW PUBLICATION

Report of Investigations 23. **GEOLOGY OF THE HYLAS AND MIDLOTHIAN QUADRANGLES, VIRGINIA**, by Bruce K. Goodwin; 51 p., 2 maps in color. Price: \$3.00 (plus 4 percent State sales tax).

The Hylas and Midlothian 7.5-minute quadrangles are located in the eastern Virginia Piedmont about 9 miles west of Richmond. Igneous, metamorphic, and sedimentary rocks are present. Igneous rocks include the Petersburg granite and the associated quartz monzonite porphyry, pegmatites, and diabase dikes. Granite gneiss, biotite gneiss, amphibolite, and metavolcanic rocks are the dominant metamorphic lithologies. Triassic sedimentary rocks in the Richmond basin consist of arkosic sandstone, shale, coarse conglomerate, and coal. Coarse gravels of probable Tertiary age mantle the upland surfaces of the Midlothian quadrangle.

The granite gneiss, biotite gneiss, and amphibolite, which are Precambrian (?) in age, have been deformed into overturned, nearly isoclinal folds. These rocks have pronounced foliation and lineations are generally well developed.

Metavolcanic rocks, which are at a lower metamorphic grade, overlie the older gneisses in angular unconformity. They are phyllitic to gneissic in texture and have also been deformed into nearly isoclinal folds. The Petersburg granite of probable late Paleozoic age is intrusive into the metavolcanic rocks.

Sedimentary rocks of Triassic age along the eastern edge of the Richmond basin are nonconformable upon the Petersburg granite. A pronounced normal fault that is offset along later normal faults forms the western boundary of the basin. Sediments were supplied to the basin from both easterly and westerly sources. Tertiary gravels lie in angular unconformity upon the eroded Triassic rocks. One of these gravels covers the upland surfaces in the Midlothian quadrangle and contains highly weathered pebbles and cobbles. Another Tertiary gravel unit occurs at lower elevations and contains fresher pebbles and cobbles.

Large quantities of crushed stone are presently being produced from igneous and metamorphic rocks within the quadrangles. In former years, coal deposits of Triassic age were actively mined. Several prospects for rutile have been made in the northwestern part of the area.

NATURE, NOT ONLY MAN, DEGRADES ENVIRONMENT¹

William T. Pecora²

Natural earth processes are by far the principal agents in modifying our environment. The ability to maintain an acceptable environment can be hindered by failure to recognize basic processes and quality patterns beyond our control.

Environmental degradation is a natural process on earth. With the intellectual development now achieved by man, it is inexcusable that we should fail to predict responses of nature consequent to our own actions. Better "housekeeping" of the earth must be practiced as man continues to take from it the things he needs and uses. If we must take from the earth to provide for ourselves, we must employ value judgment and trade-off concepts in deciding how much to take from our environment, where to take it, and how to leave it in the taking and using. Take and use we must, or we cannot survive as a species on earth.

A conflict exists between the need to develop our resources and the need to preserve our environment. A staggering amount of mineral resources, upon which the sustenance of the Nation depends, is needed. This imposes a tremendous task of new discovery and new development. The resource needs of the Nation are such that within the life span of 200 million people now living in the United States, resources to meet their needs will include 6.5 quadrillion gallons of water, 7.5 billion tons of iron ore, 1.5 billion tons of phosphate rock, and 100 million tons of copper. Water usage and energy requirements will triple by the year 2,000, and by that time, we will have to construct as many houses and other facilities as now exist in the United States.

If the earth shall provide the materials for the survival of man's society, then a prudent society must provide for an intimate understanding of the earth, inquiry must be made into the geologic processes that have operated over the span of earth history and operate today, an inventory of current and potential resources must be continued, and efforts must be made to develop new techniques for information-gathering systems.

Many people believe that man alone is degrading and polluting his environment by our modern

society. Some myths need to be destroyed, because if man is to tackle the many complex problems of environmental degradation effectively, he must first understand its forces. This is not to excuse or put aside what man has done, but rather to put man's actions in proper natural perspective. Those who speak about restoring our inherited environment to pristine states often ignore the inevitability of nature.

Natural processes are principal agents in modifying the environment as demonstrated by the following:

(1) It has been estimated that more than 100 million tons of fixed nitrogen in the form of ammonia and nitrates is annually deposited from the atmosphere to the earth as part of a natural precipitation process. In the United States alone, more than 4 million tons of table salt, 2.5 million tons of sodium sulphate, and 36 million tons of calcium compounds fall upon the land surface—all in rain water.

(2) Particulate matter and natural gases dispersed from volcanoes is a continuing phenomenon. From three eruptions alone—the Krakatua eruption in Java (1883), the Mount Katmai eruption in Alaska (1912), and the Hekla eruption in Iceland (1947)—more dust, ash, and combined gases were ejected into the atmosphere than from all of man's activities.

(3) Many have long believed that water issuing from natural springs is pure and beneficial to health because of its purity. The springs issuing into the Arkansas and Red rivers carry 17 tons of salt per minute. In the Lower Colorado River, salt springs carry 1500 tons of salt per day. The Lemonade Springs in New Mexico carry 900 pounds of sulphuric acid per million pounds of water, which is 10 times the acid concentration of most acid mine streams in the Nation. Hot Springs in Yellowstone Park is likewise many times more acidic than the typical acid stream in a coal-mining district. The Azure Yampah spring in Colorado contains 8 times the radium that Public Health Service sets as a safe limit.

(4) Lakes and ponds throughout geologic history have gone through a life cycle of birth, maturity, old age, and disappearance. No lake is truly permanent. Some of our inland lakes during their mature stage become more salty than the

¹ Excerpts from Department of Interior news release, June 8, 1970.

² Director, U. S. Geological Survey, Washington, D. C.

ocean itself. The Great Salt Lake is nearing its dying stages. Once 20,000 square miles in area (Lake Bonneville), it is now only 950 square miles. Many thousands of years ago, it was essentially a fresh water lake, fed during the Great Ice Age. Now it is about 10 times as salty as sea water.

(5) Lake Erie is not "dead," as is heard frequently. It's the shallowest of the Great Lakes, and was created about 10,000 to 20,000 years ago. Barring another Ice Age, it has several thousands of years yet to go before senility. The western part of the lake is extremely shallow, and receives a large amount of natural organic material transported from the surrounding terrain. This is where algae growth has always been present. Lake Erie has continually produced about 50% of the fish catch of the entire Great Lakes system, consistently over the past 100 years. This is not the mark of a dead lake. Green Bay, Michigan, so named by the first settlers because of the green color of the algae so prevalent in the Bay is, like the western shallow part of Lake Erie, the source of a great amount of organic matter. The food supply for aquatic life is high in these environments. The oxygen supply, unfortunately, diminishes as algae growth increases, as this portion of the lake becomes more and more shallow and as organic material is swept into the water, whether from natural or human sources. Every lake or pond, whether natural or man-made, faces a similar life history.

(6) The Nation's rivers are called dirty because of the works of man. River systems, however, are the natural transport systems for sediment washed downhill by the rains that fall upon the land. It is estimated that the Mississippi River carries into the Gulf a load of more than 2 million tons of sediment a day, which is the equivalent to the load of 40,000 freight cars. The Colorado carries about 40,000 tons a day into Lake Mead. The Paria River in Arizona is probably the dirtiest river in the world; it carries 500 times as much sediment as the Mississippi per unit volume of water. Chemicals are also transported by streams in phenomenal amounts. The Brazos River of Texas, for example, transports 25,000 tons of dissolved salt per day. Peace Creek in Florida carries twice the concentration of fluoride that is harmful to teeth. Many rivers and streams throughout the Nation have natural qualities that do not meet the Public Health standards for drinking water.

We find ourselves in the midst of a conflict between the need to develop the earth's resources, and the desire to preserve the earth's environment—both, presumably, for the salvation of mankind. Must we choose between the two concepts or can we seek balance as we move into the future? The first judgment must distinguish between danger and aesthetics; because change is inevitable in any developing society. The pace of change is a function of the choice of the people, as it should be.

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ADDITIONS TO STAFF

Mr. William B. Harris joined the Division staff on November 1, 1970 and is assisting in studies of economic geology. He received his B.S. degree in geology from Campbell College in 1966 and an M.S. degree in geology from West Virginia University in 1968. Before coming to the Division, Mr. Harris was employed as an exploration geologist with Texaco Incorporated in Tulsa, Oklahoma. He is married and has two sons.

Mr. Paul G. Nystrom, Jr. was employed by the Division on November 2, 1970. He received his B.A. degree in geology from the University of Virginia in 1967 and is currently completing requirements for an M.S. degree from the University of South Carolina. As a graduate student, he mapped several quadrangles in the Carolina Slate Belt for the South Carolina State Development Board. Mr. Nystrom is assisting in the preparation of a hydrogeologic report on Augusta and Rockingham counties. His main interests are in stratigraphy and structural geology. He is married and has one daughter.

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COMPLETION OF TOPOGRAPHIC MAP COVERAGE

Topographic maps of the 7.5-minute series are now available either as published or advance-print quadrangles for all of Virginia for the first time. They are being produced as a result of the Commonwealth of Virginia-U. S. Geological Survey cooperative topographic-mapping program. To

date, a total of 553 of the modern quadrangles have been printed, which is 68 percent those needed to cover the entire State. All advance-print maps are scheduled to be completed in published form by mid-1972. The latter maps consist of either an initial "before field completion" stereocompilation or as a later "after field completion" composite quadrangle. Both depict cultural features, streams, and topography; the composite quadrangles also have place names. Within areas of rapid cultural growth, 64 of these modern published quadrangles have already been updated. Recent urban growth depicted by magenta overprint on existing map stock is now available for the following cities and towns, and their peripheral areas: Big Stone Gap, Bristol, Charlottesville, Emporia, Harrisonburg, Lynchburg, Newport News, Pennington Gap, Pound, Richmond, Roanoke, Salem, Staunton, Suffolk, and Waynesboro. Information on the status of topographic mapping can be obtained on request from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903.

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NEW ADDRESS FOR ROCK AND MINERAL EXCHANGE

The following notice appeared in the September 1, 1970 issue of the *ESTPP Newsletter* and is here reprinted to inform teachers of the continued availability of a means to procure rock and mineral specimens.

"Rock and mineral exchange service mailings should now be sent to Janet E. Wall, Rock and Mineral Exchange Service, % The Science Department, McFarland High School, McFarland, Wisconsin 53558. Charles A. Wall and his wife Janet, both enthusiastic earth science teachers, operated the Rock and Mineral Exchange this last year while they worked on their master's degrees at Texas A & M in College Station. The time and effort that they both have spent serving teachers, secondary schools, and colleges by providing a clearinghouse for the exchange of earth science materials and ideas is phenomenal. The service has grown to include bibliographic exchanges as well. It will continue to operate from the Wall's new location in Wisconsin. Chuck will be working on an advanced degree at the University of Wisconsin, and Janet will be teaching in the science department at McFarland High School in McFarland, Wisconsin."

MELANTERITE-ROZENITE-PYRRHOTITE OCCURRENCE IN CARROLL COUNTY, VIRGINIA

Richard S. Good

A white to pale-yellowish, powdery, encrustation on massive pyrrhotite was collected recently from a surface pit 3 miles north of Galax, Carroll County, Virginia. It contained rozenite ($\text{FeSO}_4 \cdot 4\text{H}_2\text{O}$, monoclinic) as well as the common "alum" melanterite ($\text{FeSO} \cdot 7\text{H}_2\text{O}$, monoclinic) as determined by X-ray analysis.

Rozenite has only recently been recognized as a distinct mineral from triclinic siderotil ($\text{FeSO}_4 \cdot 5\text{H}_2\text{O}$). It occurs in moderately humid to dry atmospheres, whereas melanterite is present in very moist environments.

Previously reported occurrences of rozenite in Albemarle, Louisa, and Rockbridge counties, Virginia have been with pyrite or marcasite (Dietrich, 1970). The Carroll County material is on goethite-encrusted pyrrhotite which occurs in an actinolite-chlorite schist with a small amount of quartz in the Precambrian Lynchburg Formation.

REFERENCES

Dietrich, R. V., 1970, Minerals of Virginia, Virginia Polytech. Inst., Research Div. Bull. 47, 325 p.

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THE MINERAL INDUSTRY IN VIRGINIA IN 1970¹

PRELIMINARY DATA

Due largely to a record-breaking output of coal, coupled with a substantially higher unit value for this commodity, the total value of 1970 mineral output in Virginia rose to a new high of \$405.4 million, according to estimates by the Bureau of Mines, United States Department of the Interior. Value was 28 percent greater than the \$317.5 million reported in 1969, the previous record high year. Increases in the value of three commodities accounted for 98 percent of the \$87.9 million rise in total value, coal, 90 percent; stone, 5 percent; and lime, 3 percent. Of the total mineral value,

¹ Prepared by David J. Kusler, U. S. Bureau of Mines, Pittsburgh, Pennsylvania.

approximately 67 percent was contributed by fuels (predominately coal), 31 percent by nonmetals, and 2 percent by metals.

Production of bituminous coal, the leading commodity in both tonnage and value, increased for the eighth consecutive year, and was 11 percent higher than in 1969, the previous record year. Production of natural gas increased while petroleum output was unchanged.

Production of stone, next to coal in importance to the mineral economy of Virginia, rose moderately. Both crushed and dimension stone were produced; crushed stone accounted for virtually all of the output and 94 percent of the output value. Sand and gravel declined slightly in output, but gained slightly in value. Shipments of portland cement increased slightly while masonry cement sales were moderately lower than in 1969. Lime gained 20 percent in both output and value, primarily because of increased demand for industrial lime by the chemical and metallurgical industries. Among other nonmetallic and nonfuel commodities gaining in output and value were aplite, feldspar, gypsum, kyanite, and salt. Those for which declines were reported included clays and crushed soapstone.

Production of zinc was moderately lower while output of lead rose slightly. The ratio of zinc recovery to that of lead was about 5 to 1. Output of titanium concentrate (ilmenite) for pigment manufacture increased. The output of iron oxides for pigment material declined but the output value rose substantially.

Table 2. — Comparison of value of mineral production in the southeastern United States for 1969 and 1970 and percent of increase.

	1969 Value (millions)	Preliminary 1970 Value (millions)	% Increase
Alabama	\$284.7	\$339.6	12
Florida	295.3	295.3	—
Georgia	190.9	197.4	3
Kentucky	591.0	784.2	33
Maryland	83.5	88.6	6
North Carolina	90.4	94.1	4
South Carolina	55.9	55.7	—
Tennessee	205.5	215.5	5
Virginia	317.5	405.4	28
West Virginia	947.2	1,181.7	26

Table 1. — Mineral production in Virginia.¹

Mineral	1969 Quantity	1969 Value (thousands)	Preliminary 1970 Quantity	Preliminary 1970 Value (thousands)
Clays	1,677	\$ 1,504	1,467	\$ 1,460
Coal (bituminous)	35,555	192,802	39,335	272,200
Gem stones	NA	7	NA	7
Lead (recoverable content of ores, etc.)	3,358	1,000	3,479	1,095
Lime	1,072	13,653	1,290	16,422
Natural gas	2,846	845	2,980	885
Petroleum (crude)	1	W	1	W
Sand and gravel	12,140	15,954	11,915	16,122
Soapstone	4,600	12	4,000	10
Stone	33,461	58,713	36,158	62,917
Zinc ² (recoverable content of ores, etc.)	18,704	5,462	17,480	5,356
Value of items that cannot be disclosed:				
Aplite, cement (portland and masonry), feldspar, gypsum, iron oxides (pigment material), kyanite, salt, titanium concentrate (ilmenite), and data indicated by symbol W.	—	27,575	—	28,957
Total	—	\$317,527	—	\$405,431

NA Not available. W Withheld to avoid disclosing individual company confidential data.

¹ Production as measured by mine shipments, sales, or marketable production (including consumption by producers).

² Recoverable zinc valued at the yearly average price of prime western slab zinc, East St. Louis market. Value established after transportation, smelting, and manufacturing charges have been added to the value of ore at the mine.

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TOPOGRAPHIC MAPS

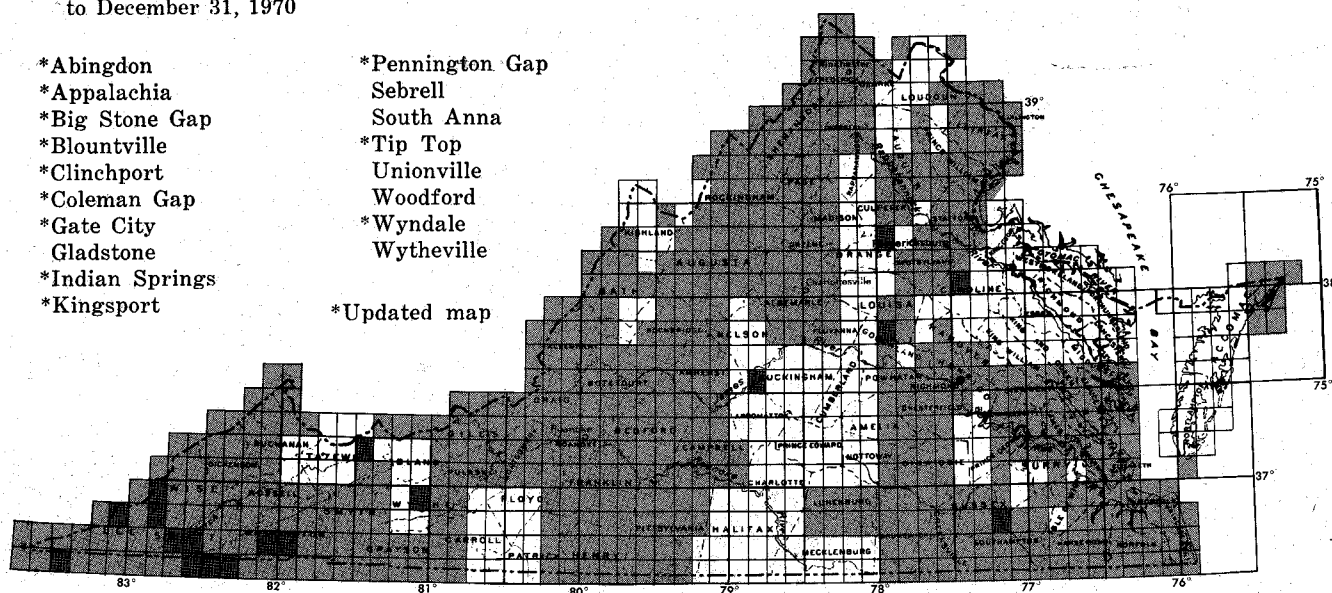
7.5-MINUTE QUADRANGLE TOPOGRAPHIC MAPS

- ☐ Advance prints and revision compilations available
- ☒ Maps published prior to October 15, 1970
- ☒ Maps published from October 15, 1970 to December 31, 1970

*Abingdon
*Appalachia
*Big Stone Gap
*Blountville
*Clinchport
*Coleman Gap
*Gate City
*Gladstone
*Indian Springs
*Kingsport

*Pennington Gap
*Sebrell
*South Anna
*Tip Top
*Unionville
*Woodford
*Wyndale
*Wytheville

*Updated map



ADVANCE PRINTS AND REVISION COMPILATIONS

Advance prints and copies of revision compilations are available at 50 cents each from the U. S. Geological Survey, Topographic Division, 1109 N. Highland St., Arlington, VA 22210.

PUBLISHED MAPS

State index is available free. Updated maps, on which recent cultural changes are indicated, are now available for certain areas of industrial, residential, or commercial growth. Published maps are available at 50 cents each from the Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903.

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